Many gamma-ray bursts go undetected, MIT mathematician estimates

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CAMBRIDGE, Mass.--An MIT researcher estimates in the Aug. 10 issue of Astrophysical Journal Letters that there are roughly 450 gamma-ray bursts or X-ray flashes occurring in the observable universe for every 1 detectable by orbiting satellites.

Shining as brightly as a million trillion suns yet seldom lasting even one minute, gamma-ray bursts (GRBs) were a great astronomical mystery only recently solved when they were conclusively shown to be linked to cataclysmic explosions called supernovae that mark the deaths of very massive stars.

Gamma-ray bursts come to us--across billions of light years of space and hence billions of years of time--from wholly random directions of the sky about once a day, but astronomers have long suspected they see only a small portion of the total number actually occurring. Until the recent gamma-ray burst/supernova link was made, proving this or even deriving a number of "actual-to-observed" bursts based on observations was exceedingly difficult.

With this link established, two scientists at MIT's Laser Interferometer Gravitational Wave Observatory (LIGO) have just derived an "actual-to-observed" ratio of 450-1. That is, there are roughly 450 GRBs occurring in the observable universe for every one that's detectable by orbiting satellites designed to look for them. This is a figure that not only utilizes the GRB-supernova link but also agrees well with a previous, independently derived ratio that did not use such a link.

These findings could have important consequences in the long hunt for elusive gravitational waves--tiny ripples in space-time predicted by Einstein's theory of general relativity but as yet never directly observed.

"Our 450-1 figure closely agrees with a 500-1 ratio derived in 2001 by other scientists, which makes us more confident in these results," said Maurice van Putten, assistant professor of applied mathematics. Van Putten collaborated with post-doctoral researcher Tania Regimbau in the study. "The earlier figure was based on a method totally independent of the supernova association involving spectral characteristics of the gamma-ray emissions themselves."

To derive their figure, van Putten and Regimbau assumed the now-standard "collapsar" model of GRBs. In that model, the core of an especially massive star undergoes a gravitational collapse (likely resulting in a black hole), producing a massive pressure wave that blasts out of the star in a particular direction. The blast wave collides with dust and gas in the surrounding interstellar medium at velocities near that of light, producing gamma-ray emissions. The type of star used in the collapsar model is also the type of star that ends its life in a supernova.

SUPERNOVAE EVIDENCE

What was missing was observational evidence linking GRBs to supernovae. That evidence was provided by a burst detected on March 29, 2003 (and therefore dubbed GRB 030329) by the HETE satellite, one of the main GRB-seeking satellites. That burst was so close in astronomical terms--roughly 2 billion light years away--that astronomers were able to study the "afterglow" light of progressively less energetic radiation.

What astronomers saw in the spectral analysis of the light curves was the unmistakable signature of a supernova, including the presence of oxygen emission lines excited in the blast. This information provided powerful support to a previous, even closer blast on April 25, 1998 that had provided a less conclusive link between supernovae and GRBs.

Once the GRB-supernovae link was established, van Putten and Regimbau used a "very precious" sample of 33 GRBs whose distances (unlike most) are well known, to establish a mathematical relationship between how bright a given burst is and the rate at which the massive stars form and die.

They could do this because the massive stars involved in GRBs and supernovae live for only a few tens of millions of years, as opposed to billions of years. This fact, van Putten said, means such "massive stars essentially die at their place of birth."

One aspect of the collapsar model is that the burst (which precedes the actual supernova explosion) occurs along a particular axis in both directions, as opposed to a symmetric, radial one. Since axes of stars are oriented randomly throughout the universe, we detect only those bursts along or near whose axis the Earth happens to lie.

This effect is known as "beaming" and it means the angle through which the blast of energy is seen is relatively small for most observed blasts--no more than a few degrees of sky. Van Putten said this "beaming" effect is factored into their figure because the relationship is based on peak brightness.

A BOON TO WAVE SEARCH

Van Putten said the confirmation that there are so many more GRBs than we actually detect is potentially a boon in the quest to find gravitational waves. These minute waves in space-time are thought to be produced by massive objects undergoing extreme events, such as the formation of new black holes or collision-coalescence of existing black holes or neutron stars. Since GRBs usually mark the creation of a new black hole, gravitational waves ought to be emitted. And unlike the beamed electromagnetic energy from GRBs, gravitational waves should travel out more or less smoothly in all directions.

Van Putten said knowing a ratio of actual to observed GRBs will help LIGO precisely because most GRBs are so distant that their gravitational waves won't be detectable by this array. Instead, the findings will give astronomers a sense of how often to expect a detectable gravitational wave produced by a sufficiently close GRB.

"This is an important finding for LIGO because these findings can give us a good handle on the local gravitational-wave event rate. It doesn't matter if the burst is beamed toward us or not because the gravitational wave energy is not beamed," van Putten said.

"Given what LIGO is capable of seeing, and using our results, we would expect an event rate of perhaps one per year, as opposed to one in 450 years, which would be hopeless," he said.

George R. Ricker, principal investigator for the MIT-run High Energy Transient Explorer (HETE2) satellite, hailed the findings as just the kind of success for which he and his colleagues had hoped.

"The HETE mission is rapidly transforming GRBs from vague cosmic mysteries into incisive cosmological probes. This new work is exactly the kind of stimulating research which we dreamed HETE's success would bring about," Ricker said.

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